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(54) Title: **SUPERAGONISTS AND ANTAGONISTS OF H IL-6, AND 3D MODELLING METHOD FOR THEIR SELECTION**

(57) Abstract

It is known that the ligands of the group of cytokines similar to Interleukin 6 (IL-6), that is Oncostatin M (OSM), Leukemia Inhibitory Factor (LIF), Ciliary Neurotrophic Factor (CNTF) and Interleukin 11 (IL-11), induce the formation of a receptor complex of which the membrane molecule gp 130 is a part. The present invention refers to a methodology for selecting superagonists, antagonists and superantagonists of human interleukin-6 comprising the following operations: comparing the amino acid sequence of bovine granulocyte colony stimulating factor (bG-CSF) with the sequence of said hormone; and on the basis of the above comparison; formulating a three-dimensional model of said hormone, which allows the identification of residues that form the site of interaction with the specific receptor (Site 1) and those that constitute the site of interaction with gp 130 (Site 2) respectively. The invention allows the identification of these sites in human interleukin-6 and the isolation of variants having, with respect to the wild type hormone, a greater affinity for the specific receptor (superagonists and superantagonists) or affinity for gp 130 reduced or abolished (antagonists and superantagonists). The figure shows a scheme illustrating the methodoly applied to identify site 1 and site 2 in the case of human interleukin-6. The invention also describes the obtaining of specific superagonists and superantagonists of interleukin-6 and the use of superantagonists as low dose inhibitors of the growth of human myeloma cells dependent on wild type interleukin-6.

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Superagonists and antagonists of h IL-6, and 3D modelling method for their selection

DESCRIPTION

5 The present invention relates to a methodology for selecting superagonists, antagonists and superantagonists of human interleukin-6 (hereinafter referred to also as h IL-6 or IL-6) based on three-dimensional modelling.

10 As is known, WO 92/21029 to Genentec Inc. teaches a method for determination of agonists or antagonists of growth hormones and ligands with a similar structural conformation. The potential agonists and antagonists are put into contact with a receptor for the hormone and this causes formation of a ternary complex consisting of a 15 molecule of the potential agonist or antagonist and two molecules of such receptor for the hormone to be agonized or antagonized. Dimerization of receptors induced by a ligand molecule allows to conclude that the ligand has two different interaction sites (site 1 and site 2), on 20 which it is possible to operate using mutagenesis to generate agonists or antagonists.

It is known that the ligands in the group of cytokines similar to Interleukin 6 (IL-6), that is Oncostatin M (OSM), Leukemia Inhibitory Factor (LIF), 25 Ciliary Neurotrophic Factor (CNTF), and Interleukin 11 (IL-11), induce the formation of a receptor complex of which the membrane molecule gp 130 is a part. In this receptor complex the specific receptor for each of these cytokines and the membrane molecule gp 130 are always 30 present as common elements. It is thus possible to formulate the hypothesis that site 1 and site 2 bind to two different molecules in this class of hormones: site 1 to the specific receptor and site 2 to gp 130. Identification of the two sites is made possible, as will 35 be seen more clearly from the following, by construction of a three-dimensional model of the receptor complex based on the functional similarity between sequences of

the human growth hormone (hGH) receptor and sequences of the receptors for the hormones in question. Isolation of variants that, with respect to the wild type hormone, have a greater affinity for the specific receptor (superagonists or superantagonists) is obtained by construction of filamentous phage libraries, for example M13, carrying the hormone, both in the wild type and mutant version.

According to the invention, the difference between the three-dimensional model, for example of IL-6, adopted here and the one adopted in WO92/21029 leads to identify different residues in helix A and C as constituents of site 2. In fact, according to present invention, for the construction of the IL-6 model not the growth hormone, but the structure of a different cytokine was used as template.

Modelling of the human interleukin 6 molecule is performed as follows. It is known, from data available in scientific literature, that the amino acidic sequence of human interleukin 6 shows similarities with that of the granulocyte colony stimulating factor (G-CSF). The three-dimensional structure of bovine granulocyte colony stimulating factor (bG-CSF), determined using X-ray crystallography, was used as template to develop a three-dimensional model of human IL-6 from residue 16 to 184. Firstly, the amino acidic sequence of human IL-6 was aligned with that of bG-CSF. On the basis of the derived alignment, the amino acidic residues in the bG-CSF three-dimensional structure were replaced by the corresponding residues of human IL-6 using molecular modelling program in a computerized interactive graphic unit. In the positions in which alignment involves either deletions or insertions (which suggests a different local structure in the interleukin 6 molecule) adjustments were made by applying the options provided by the molecular modelling program.

This three-dimensional model of interleukin 6, based on the bG-CSF structure, has enabled the identification of the two sites of interaction between human interleukin 6 and its two receptors: the low affinity receptor gp 80 (site 1) and the high affinity signal transducer receptor gp 130 (site 2). The following procedure was used to identify the two sites. From sequence comparison it is known that all the members of the family of hematopoietic receptors are related to each other by the fact that they share a domain, known as the cytokine binding domain. This similarity of sequences also indicates a high probability of structural similarity in corresponding parts of the various receptors, including the two interleukin 6 receptors, gp 80 and gp 130. The observation that the cytokines that bind to these receptors all have (or are predicted to have) a similar structure, that is a four helix bundle, strongly supports the notion that the interaction between these cytokines and their receptors, by means of the cytokine binding domain, must be very similar - albeit not identical - in biologically active complexes.

Considering that the three-dimensional structure of one of these receptor complexes (the complex made by growth hormone and the extra-cellular domain of the dimeric receptor for the growth hormone, i.e. GHbp) has been determined by means of X-ray crystallography, our bG-CSF built model of human interleukin 6 allows us to identify the potential sites of interaction between interleukin 6 and its two receptors gp 80 (site 1) and gp 130 (site 2). This has been accomplished, according to the present invention, by constructing a structural model of gp 80 and gp 130 based on the coordinates furnished by the X-ray crystallographic structure of the growth hormone receptor, and by substituting in such complex the growth hormone with our bG-CSF built model of human interleukin-6 (see fig. 1).

As is known, interleukin 6 is a polypeptide of 184 amino acids which, as described, belongs to the class of helical cytokines. Interleukin 6 is a multi-functional cytokine produced by various cell types. It acts as a differentiation and growth factor on cells of various lineages, such as for example cells in the immune system, hepatocytes, kidney cells, hematopoietic stem cells, keratinocytes and neurones.

Production of superagonists of interleukin 6 would allow the use of therapeutic doses lower than those required with wild type interleukin 6 in the treatment of numerous serious diseases. In fact, interleukin 6 has important and promising applications in the treatment of breast cancer, leukemia, and infectious diseases or diseases connected with disorders of bone marrow progenitor cells.

In addition superagonists of IL-6 could be used in protocols for ex vivo expansion of hematopoietic progenitor cells both in bone marrow transplantation and gene therapy.

On the other hand the production of antagonists or superantagonists of human interleukin 6 would allow inhibition of interleukin 6 in numerous diseases characterized by its excessive production, such as chronic autoimmune diseases, myeloma/plasmacytoma, post-menopausal osteoporosis and cancer cachexia.

The methodology for the selection of superagonists, antagonists or superantagonists of interleukin-6, according to the present invention, comprises the following operations:

- comparing the amino acid sequence of bovine granulocyte colony stimulating factor (bG-CSF) with the sequence of said hormone; and
- on the basis of the above comparison,
- 35 formulating a three dimensional model of said hormone, which allows the identification of residues that form the site of interaction with the specific receptor (Site I)

and those that constitute the site of interaction with gp 130 (Site 2) respectively.

For selection of superagonists of interleukin 6, the methodology according to the present invention further comprises the following additional operations:

- production of a series of phage libraries containing mutations of the following wild type residues of interleukin 6 (present in the form of fusion product with filamentous phage proteins):

10 helix A:

Ser 22, Glu 23, Asp 26, Arg 30, Leu 33, Ser 37, Arg 40, Glu 42;

loop AB:

Ser 52, Ser 53, Ala 56, Leu 57, Glu 59, Asn 60, Leu 62, 15 Leu 64, Pro 65, Lys 66,

Met 67, Ala 68, Glu 69, Lys 70, Asp 71, Phe 74, Gln 75, Ser 76;

helix D:

20 His 164, Leu 165, Arg 168, Ser 169, Lys 171, Glu 172, Phe 173, Gln 175, Ser 176, Ser 177, Leu 178, Arg 179, Ala 180, Leu 181, Arg 182, Gln 183, Met 184.

- selection, from the mixed population of phages belonging to each individual phage library and expressing interleukin 6 mutants, of that or those with an affinity 25 for the specific receptor greater than that of wild type interleukin; and

- identification of the best receptor binder amino acid sequence or sequences by sequencing of the DNA extracted from the selected phage particles.

30 In this case, a series of phage libraries can be produced containing mutations of said wild type residues of interleukin 6 present as a fusion product with the M13 pIII protein.

The methodology for selecting antagonists of interleukin 6 according to the present invention comprises - along with the operations indicated above for

molecular modelling of the human IL-6 protein and its receptor chains - the following operations:

- mutagenesis of the residues identified to form part of the site of interaction with gp 130 (Arg 30, Tyr 31, Gly 35, Ser 37, Ala 38, Ser 118, Lys 120, Val 121, Gln 124, Phe 125, Gln 127, Lys 128 and Lys 129), using conventional molecular biology techniques;

5 - evaluation of biological activity and affinity for the specific interleukin 6 receptor of the mutants produced as above, in order to identify variants of interleukin 6 whose affinity for the specific receptor is normal and that show reduction or loss of the biological activity; and

10 - evaluation of the above variants of interleukin 6 as antagonists for the biological activity of wild type interleukin 6 on human cell lines.

In case of obtaining of superantagonists of interleukin 6 by combination of the variants of amino acid sequences responsible for antagonist activity, 20 identified as above, with amino acid mutations responsible for an increased affinity of the specific receptor for interleukin 6.

In the methodology for obtaining antagonists or superantagonists of interleukin 6, the mutagenesis of the residues identified as above can be performed using a molecular biology technique chosen from the group comprising Polymerase Chain Reaction, Primer Extension, Oligonucleotide Directed Mutagenesis, and combinations thereof.

30 The present invention is not limited to the methodology for selection of superagonists, antagonists or superantagonists of interleukin 6. On the contrary, it extends to molecules obtainable by said methodology cⁱ selection, i.e. to: superagonists of h IL-6, with the exception of the molecule called IL-6 IRA and carrying the following three substitutions Gln175Ile/Ser176Arg/Gln163Ala; antagonists of h IL-6,

with the exception of three molecules with the following substitutions:

Tyr31Asp/Gly35Phe/Ser118Arg/Val121Asp (DFRD)

Tyr31Asp/Gly35Phe/Ser118Phe/Val121Asp (DFFD)

5 Tyr31Asp/Gly35Phe/Ser118Leu/Val121Asp (DFLD);

and superantagonists of h IL-6, with the exception of the molecule called Sant1 and carrying the following seven substitutions: Tyr31Asp/Gly35Phe/Ser118Arg/Val121Asp/Gln175Ile/Ser176Arg/Gln183Ala.

10 Up to this point a general description of the subject of the present invention has been given. With the aid of the following examples a detailed description of specific embodiments of the invention will now be given, with the purpose of giving a better understanding 15 of the objects, characteristics, advantages and methods of application thereof.

Figure 1 shows a scheme illustrating the methodology applied to identify site 1 and site 2 in the case of human interleukin 6.

20 Figure 2 shows the increase in potency of three superantagonists according to the invention, i.e. Sant 3, Sant 4 and Sant 5, over antagonist Tyr31Asp/Gly35Phe/Ser118Arg/Val121Asp (the one letter codes have been used in the figure), with the increase of concentration.

25 DEPOSITS

E.Coli K12 bacteria - transformed using the plasmid pHenΔhIL-6 containing, from the recognition site of the restriction enzyme SalI to that for the restriction enzyme NotI, a nucleotidic sequence coding for the amino 30 acid sequence of wild type human interleukin 6 - have been deposited on 10/6/1993 with The National Collection of Industrial and Marine Bacteria Ltd. (NCIMB), Aberdeen, Scotland, UK, with access number NCIMB 40563.

Example 1

35 Application of the methodology according to the present invention for the selection of superagonists os

metastases in the AB loop

bacteriophage to generate the phage library (a library of phasmids).

The library underwent selection by incubation with magnetic beads coated with monoclonal antibody directed against shrIL-6R and in the presence of shrIL-6R and shrgp130. The phasmid population eluted at pH 3.6 was then amplified in bacteria. After four cycles of selection-amplification, randomly selected phasmids were sequenced over the mutagenized region, the corresponding mutant interleukin 6 proteins were produced in the periplasmic space of the appropriate bacterial strain and tested for interleukin 6 specific receptor binding. Table 1 shows that, using the methodology according to the present invention, it is possible to select variants of interleukin 6 having an additional increase in the affinity for the specific receptor, molecules with mutations both in helix D and in region A-B.

TABLE 1

Receptor binding properties in variants of interleukin 6-IRA containing additional mutations in the residues 71, 20 74, 75 and 76 of the region A-B

Position	71	74	75	76	Receptor binding (%)
wild type	Asp	Phe	Gln	Ser	100%
IL-6IRA	Asp	Phe	Gln	Ser	450%
phasmid D3-3	Asp	Tyr	Phe	Ile	2350%
phasmid D4-1	Asp	Tyr	Tyr	Val	2750%
phasmid D3-7	Asp	Phe	Tyr	Ile	2770%
30 phasmid D4-19	Asp	Phe	Tyr	Ser	1800%
phasmid D4-20	Asp	Phe	Tyr	Lys	4200%
phasmid D3-16	Asp	Phe	Tyr	Leu	1450%
phasmid D4-17	Asp	Phe	Phe	Ile	2430%

35 Example 2

Application of the methodology according to the present invention for obtaining superantagonists of interleukin 6

The four mutations Tyr31Asp/Gly35Phe/Ser118Arg/
Val121Asp (DFRD) confer antagonistic properties as
described in WO95/00852. These four mutations were
combined with mutations capable of increasing the
specific receptor binding capacity (described in example
1), using the Polymerase Chain Reaction (PCR) molecular
biology technique. More specifically:

the super-binder mutations on helix D and region AB
of the phasmid D 3-7 (described in example 1), to create
the mutant protein Sant 3;

the super-binder mutations on helix D and region AB
of the phasmid D 3-3 (described in example 1), to create
the mutant protein Sant 4;

the super-binder mutations on helix D and region AB
of the phasmid D 4-20 (described in example 1), to create
the mutant protein Sant 5.

The mutant proteins, containing nine (Sant 3 and
Sant 5) or ten (Sant 4) amino acid substitutions, were
tested both for their specific interleukin-6 receptor
binding, and for their ability to antagonize the
biological activity of interleukin-6 on human hepatoma
and myeloma cells. Table 2 and fig. 2 show the specific
receptor binding properties of DFRD and of Sant 3, Sant 4
and Sant 5 along with the concentrations (expressed in
nanograms of mutant per milliliter of culture medium) of
mutant necessary to inhibit 50% of interleukin 6
biological activity (hepatoma cells were stimulated with
4 nanograms of wild type interleukin 6 per milliliter of
culture medium, while myeloma cells were stimulated with
0.1 nanograms of interleukin 6 per milliliter of culture
medium, due to the higher sensitivity of the latter cells
to wild type interleukin 6).

TABLE 2

Inhibition of wild type interleukin 6 biological activity
on both human hepatoma and myeloma cells as a function of
the mutant antagonists' specific interleukin-6 receptor
binding capacity

	Antagonist	Receptor binding (% of wild type)	50% inhibition of interleukin 6 activity on: hepatoma cells Hep3B	myeloma cells XG-1
5	DFRD	97%	164 ng/ml	190.0 ng/ml
	Sant 3	2800%	2.4 ng/ml	1.85 ng/ml
	Sant 4	2000%	2.7 ng/ml	3.90 ng/ml
	Sant 5	4500%	2.3 ng/ml	2.45 ng/ml

10 As can be seen from the table, the introduction of the amino acid substitutions described in example 1 has at once increased the specific receptor binding capacity of the parental mutant DFRD and decreased the amount of antagonist needed to inhibit 50% of wild type interleukin 6 biological activity on both cell lines tested, therefore generating very effective and strong interleukin 6 superantagonists.

15

SEQUENCE LISTING

GENERAL INFORMATION

(i) APPLICANT: ISTITUTO DI RICERCHE DI BIOLOGIA
MOLECOLARE P. ANGELETTI S.p.A.

5 (ii) TITLE OF INVENTION: A METHODOLOGY FOR SELECTING
SUPERAGONISTS, ANTAGONISTS AND SUPERANTAGONISTS OF HUMAN
INTERLEUKIN-6 BASED ON RECEPTOR COMPLEX THREE DIMENSIONAL
MODELLING

10 (iii) NUMBER OF SEQUENCES: 3
(iv) CORRESPONDENCE ADDRESS:
(A) ADDRESSEE: Società Italiana Brevetti
(B) STREET: Piazza di Pietra, 39
(C) CITY: Rome
(D) COUNTRY: Italy
15 (E) POSTAL CODE: I-00186

15 (v) COMPUTER READABLE FORM:
(A) MEDIUM TYPE: Floppy disk 3.5" 1.44 MBYTES
(B) COMPUTER: IBM PC compatible
(C) OPERATING SYSTEM: PC DOS/MS DOS Rev 6.22
20 (D) SOFTWARE: Microsoft Word 6.0

20 (viii) ATTORNEY INFORMATION
(A) NAME: DI CERBO, Mario (Dr.)
(B) REGISTRATION NUMBER:
(C) REFERENCE: RM/X88471/PC-DC

25 (ix) TELECOMMUNICATION INFORMATION
(A) TELEPHONE: 06/6785941
(B) TELEFAX: 06/6794692
(C) TELEX: 612287 ROPAT

30 (1) INFORMATION FOR SEQ ID NO: 1:
(i) SEQUENCE CHARACTERISTICS
(A) LENGTH: 555 base pairs
(B) TYPE: nucleic acid

(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

35 (ii) MOLECULE TYPE: DNA
(iii) HYPOTHETICAL: no
(iv) ANTISENSE: no

(v) FRAGMENT TYPE: internal
(vii) IMMEDIATE SOURCE:
(A) SYNTHESIS: production in bacteria
(ix) FEATURE:
5 (A) NAME: IL-6 cDNA
(C) IDENTIFICATION METHOD: polyacrylamide
gel
(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 1:
CCA GTA CCC CCA GGA GAA GAT TCC AAA GAT GTA GCC GCC CCA CAC AGA 48
10 Pro Val Pro Pro Gly Glu Asp Ser Lys Asp Val Ala Ala Pro His Arg
1 5 10 15
CAG CCS CTC ACG AGC TCA GAA CGA ATT GAC AAA CAA ATT CGG TAC ATC 96
Gln Pro Leu Thr Ser Ser Glu Arg Ile Asp Lys Gln Ile Arg Tyr Ile
20 25 30
15 CTC GAC GGC ATC TCA GCC TTA AGA AAG GAG ACA TGT AAC AAG AGT AAC 144
Leu Asp Gly Ile Ser Ala Leu Arg Lys Glu Thr Cys Asn Lys Ser Asn
35 40 45
ATG TGT GAA AGC AGC AAA GAG GCA CTG GCA GAA AAC AAC AAC CTG AAC CTT 192
Met Cys Glu Ser Ser Lys Glu Ala Leu Ala Glu Asn Asn Leu Asn Leu
20 50 55 60
CCA AAG ATG GCT GAA AAA GAT GGA TGC TTC CAA TCT GGA TTC AAT GAG 240
Pro Lys Met Ala Glu Lys Asp Gly Cys Phe Gln Ser Gly Phe Asn Glu
65 70 75 80
GAG ACT TGC CTG GTG AAA ATC ATC ACT GGT CTT TTG GAG TTT GAG GTA 288
25 Glu Thr Cys Leu Val Lys Ile Ile Thr Gly Leu Leu Glu Phe Glu Val
85 90 95
TAC CTA GAG TAC CTC CAG AAC AGA TTT GAG AGT AGT GAG GAA CAA GCC 336
Tyr Leu Glu Tyr Leu Gln Asn Arg Phe Glu Ser Ser Glu Glu Gln Ala
100 105 110
30 AGA GCT GTC CAG ATG AGT ACA AAA GTC CTG ATC CAG TTC CTG CAG AAA 384
Arg Ala Val Gln Met Ser Thr Lys Val Leu Ile Gln Phe Leu Gln Lys
115 120 125
AAG GCA AAG AAT CTA GAT GCA ATA ACC ACC CCT GAC CCA ACC ACA AAT 432
Lys Ala Lys Asn Leu Asp Ala Ile Thr Thr Pro Asp Pro Thr Thr Asn
35 130 135 140

GCC AGC CTG CTG ACG AAG CTG CAG GCA CAG AAC CAG TGG CTG CAG GAC 480
Ala Ser Leu Leu Thr Lys Leu Gln Ala Gln Asn Gln Trp Leu Gln Asp
145 150 155 160
ATG ACA ACT CAT CTC ATT CTG AGA TCT TTT AAG GAG TTC CTG CAG TCC 528
5 Met Thr Thr His Leu Ile Leu Arg Ser Phe Lys Glu Phe Leu Gln Ser
165 170 175
AGC CTG AGG GCT CTT CGG CAA ATG TAG 555
Ser Leu Arg Ala Leu Arg Gln Met
180

10 (2) INFORMATION FOR SEQ ID NO: 2

(i) SEQUENCE CHARACTERISTICS

(A) LENGTH: 95 base pairs

(B) TYPE: nucleic acid

15 (C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: synthetic DNA

(iii) HYPOTHETICAL: no

(iv) ANTISENSE: no

(v) FRAGMENT TYPE: internal

20 (vi) IMMEDIATE SOURCE:

(A) SYNTHESIS: oligonucleotide

synthesizer

(ix) FEATURE:

(A) NAME: DFQS

25 (C) IDENTIFICATION METHOD: polyacrylamide

gel

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 2:

GTGAGAGCTC CAAAGAGGCA CTGGCAGAAA ACAACCTGAA CCTTCCAAAG ATGGCTGAAA 60
AANNSSGGATG CNNSNNSNNS GGATTCAATG AGGAG 95

30 (3) INFORMATION FOR SEQ ID NO: 3

(i) SEQUENCE CHARACTERISTICS

(A) LENGTH: 72 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

35 (ii) MOLECULE TYPE: synthetic DNA

(iii) HYPOTHETICAL: no

- 15 -

(iv) ANTISENSE: yes

(v) FRAGMENT TYPE: internal

(vii) IMMEDIATE SOURCE:

(A) SYNTHESIS: oligonucleotide

5 synthesizer

(ix) FEATURE:

(A) NAME: AB primer

(C) IDENTIFICATION METHOD: polyacrylamide

gel

10 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 3:

GGCCTCTAGA TATACCTCAA ACTCCAAAAG ACCAGTGATG ATTTTCACCA GGCAAGTCTC 60
CTCATTGAAT CC

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CLAIMS

1. A methodology for selecting superagonists, antagonists and superantagonists of interleukin 6 comprising the following operations:

5 - comparing the amino acid sequences of bovine granulocyte colony stimulating factor (bG-CSF) with the sequence of said hormone; and

10 - on the basis of the above comparison, formulating a three-dimensional model of said hormone, which allows the identification of residues that form the site of interaction with the specific receptor (site 1) and those that constitute the site of interaction with gp 130 (site 2) respectively.

15 2. The methodology for selecting superagonists of interleukin 6 according to claim 1, further comprising the following additional operations:

20 - production of a series of phage libraries containing mutations of the following wild type residues of interleukin 6 present in the form of a fusion product with filamentous phage proteins Ser 22, Glu 23, Asp 26, Arg 30, Leu 33, Ser 37, Arg 40, Glu 42, Ser 52, Ser 53, Ala 56, Leu 57, Glu 59, Asn 60, Leu 62, Leu 64, Pro 65, Lys 66, Met 67, Ala 68, Glu 69, Lys 70, Asp 71, Phe 74, Gln 75, Ser 76, His 164, Leu 165, Arg 168, Ser 169, Lys 171, Glu 172, Phe 173, Gln 175, Ser 176, Ser 177, Leu 178, Arg 179, Ala 180, Leu 181, Arg 182, Gln 183, Met 184;

25 30 - selection, from the mixed population of phages expressing interleukin 6 mutants, of that or those with an affinity for the specific receptor greater than that of wild type interleukin; and

35 - identification of the best amino acid sequence or sequences binding the receptor by sequencing of the DNA extracted from the selected phage particles,

35 with the exception of the h IL-6 molecule carrying the three substitutions Gln175Ile/Ser176Arg/Gln183Ala.

3. The methodology for selecting superagonists of interleukin 6 according to claim 2, in which a series of phage libraries are produced, containing mutants of said wild type residue of interleukin 6 present as a product of fusion with protein pIII of M13.

4. The methodology for selecting antagonists of interleukin 6 according to claim 1, further comprising the following additional operations:

- mutation of the residues identified in claim 1, to form part of the site of interaction with gp 130 (Arg 30, Tyr 31, Gly 35, Ser 37, Ala 38, Ser 118, Lys 120, Val 121, Gln 124, Phe 125, Gln 127, Lys 128 and Lys 129), using conventional molecular biology techniques;

- evaluation of biological activity and affinity with the specific interleukin 6 receptor of the mutants produced as above, in order to identify variants of interleukin 6 whose affinity to the specific receptor is intact and that show reduction or loss of the biological activity; and

- evaluation of the above variants of interleukin 6 as antagonists for the biological activity of wild type interleukin 6,

with the exception of the three h IL-6 molecules with the following substitutions:

Tyr31Asp/Gly35Phe/Ser118Arg/Val121Asp

Tyr31Asp/Gly35Phe/Ser118Phe/Val121Asp

Tyr31Asp/Gly35Phe/Ser118Leu/Val121Asp.

5. The methodology for selecting superantagonists of interleukin 6 according to claims 2 to 4 by combination of the variations of amino acid sequences responsible for antagonist activity, indicated above, with amino acid variations responsible for an increased affinity of the specific receptor for interleukin 6, with the exception of the h IL-6 molecule carrying the seven substitutions

Tyr31Asp/Gly35Phe/Ser118Arg/Val121Asp/Gln175Ile/Ser176Arg/Gln183Ala

6. The methodology for selecting antagonists or superantagonists of interleukin 6 according to claim 5, in which the mutagenesis of the residues identified as above is performed using a molecular biology technique chosen from the group comprising Polymerase Chain Reaction, Primer Extension, Oligonucleotide Directed Mutagenesis, and combinations thereof.

5 7. Interleukin 6 mutants according to claim 3, both showing an increased affinity for the specific receptor and containing the mutations Glutamine 175 Isoleucine, Serine 176 Arginine and Glutamine 183 Alanine, together with multiple substitutions in the Phenylalanine 74, Glutamine 75 and Serine 76 residues.

10 8. Interleukin-6 mutants according to claim 7, showing an increased affinity for the specific receptor and containing mutations chosen from the group comprising:

15 - Glutamine 75 Tyrosine, Serine 76 Isoleucine, Glutamine 175 Isoleucine, Serine 176 Arginine and Glutamine 183 Alanine;

20 - Phenylalanine 74 Tyrosine, Glutamine 75 Phenylalanine, Serine 76 Isoleucine, Glutamine 175 Isoleucine, Serine 176 Arginine and Glutamine 183 Alanine; and

25 - Glutamine 75 Tyrosine, Serine 76 Lysine, Glutamine 175 Isoleucine, Serine 176 Arginine and Glutamine 183 Alanine, said mutants exhibiting an affinity for the specific receptor increased 27.7 times, 23.5 times and 42 times, respectively.

30 9. Human interleukin-6 mutants having simultaneous substitution of the residues 31, 35, 74, 75, 76, 118, 121, 175, 176, 183 obtainable from claims 4 to 6 and which, by combining their antagonist properties to a greater affinity for the receptor, have the effect of superantagonists at low doses.

35 10. Human interleukin-6 mutants according to claim 9, with mutations chosen from the group comprising:

- Tyrosine 31 Aspartic acid, Glycine 35 Phenylalanine, Serine 118 Arginine, Valine 121 Aspartic acid, Glutamine 75 Tyrosine, Serine 76 Isoleucine, Glutamine 175 Isoleucine, Serine 176 Arginine and 5 Glutamine 183 Alanine;

- Tyrosine 31 Aspartic acid, Glycine 35 Phenylalanine, Serine 118 Arginine, Valine 121 Aspartic acid, Phenylalanine 74 Tyrosine, Glutamine 75 Phenylalanine, Serine 76 Isoleucine, Glutamine 175 10 Isoleucine, Serine 176 Arginine and Glutamine 183 Alanine; and

- Tyrosine 31 Aspartic acid, Glycine 35 Phenylalanine, Serine 118 Arginine, Valine 121 Aspartic acid, Glutamine 75 Tyrosine, Serine 76 Lysine, Glutamine 15 175 Isoleucine, Serine 176 Arginine and Glutamine 183 Alanine,

said mutants being capable of inhibiting the biological activity of wild type interleukin 6 on sensitive human cells including myeloma cells the growth 20 of which is IL-6-dependent.

11. Use of the superagonists according to claim 7 or 8 for the preparation of drugs for therapy of thrombocytopenia in man and for the ex vivo expansion of human hematopoietic progenitor cells for bone marrow 25 transplantation and gene therapy.

12. Use of the interleukin-6 mutants according to claim 10 for the preparation of drugs for treatment of diseases characterized by overproduction of interleukin-6, and in particular of multiple myeloma, rheumatoid 30 arthritis, postmenopausal osteoporosis and systemic lupus erythematosus.

Construction of the Model

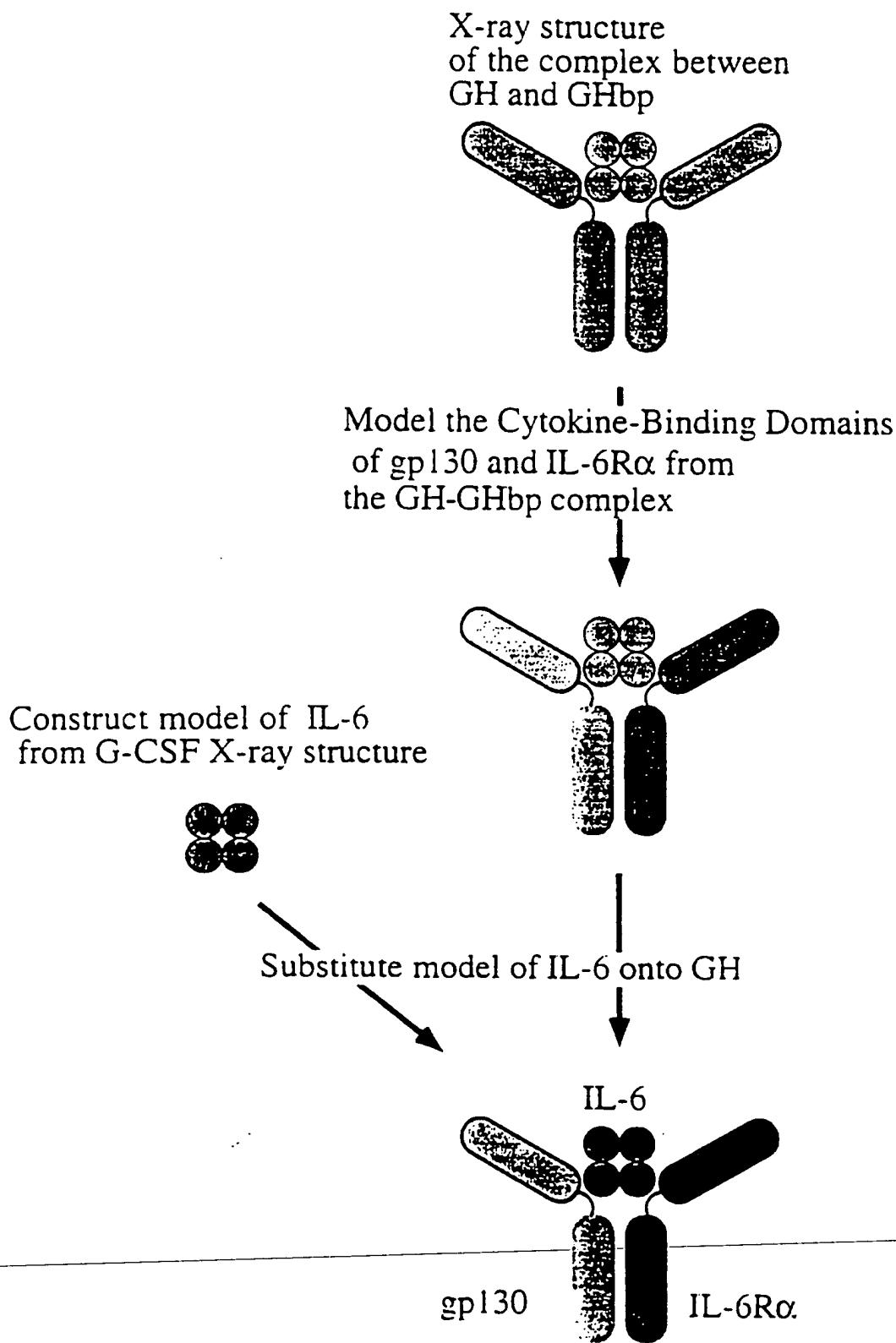


FIG. 1

Increase of potency of Sant3, Sant4 and Sant5 over antagonist Y31D/G35F/S118R/V121D

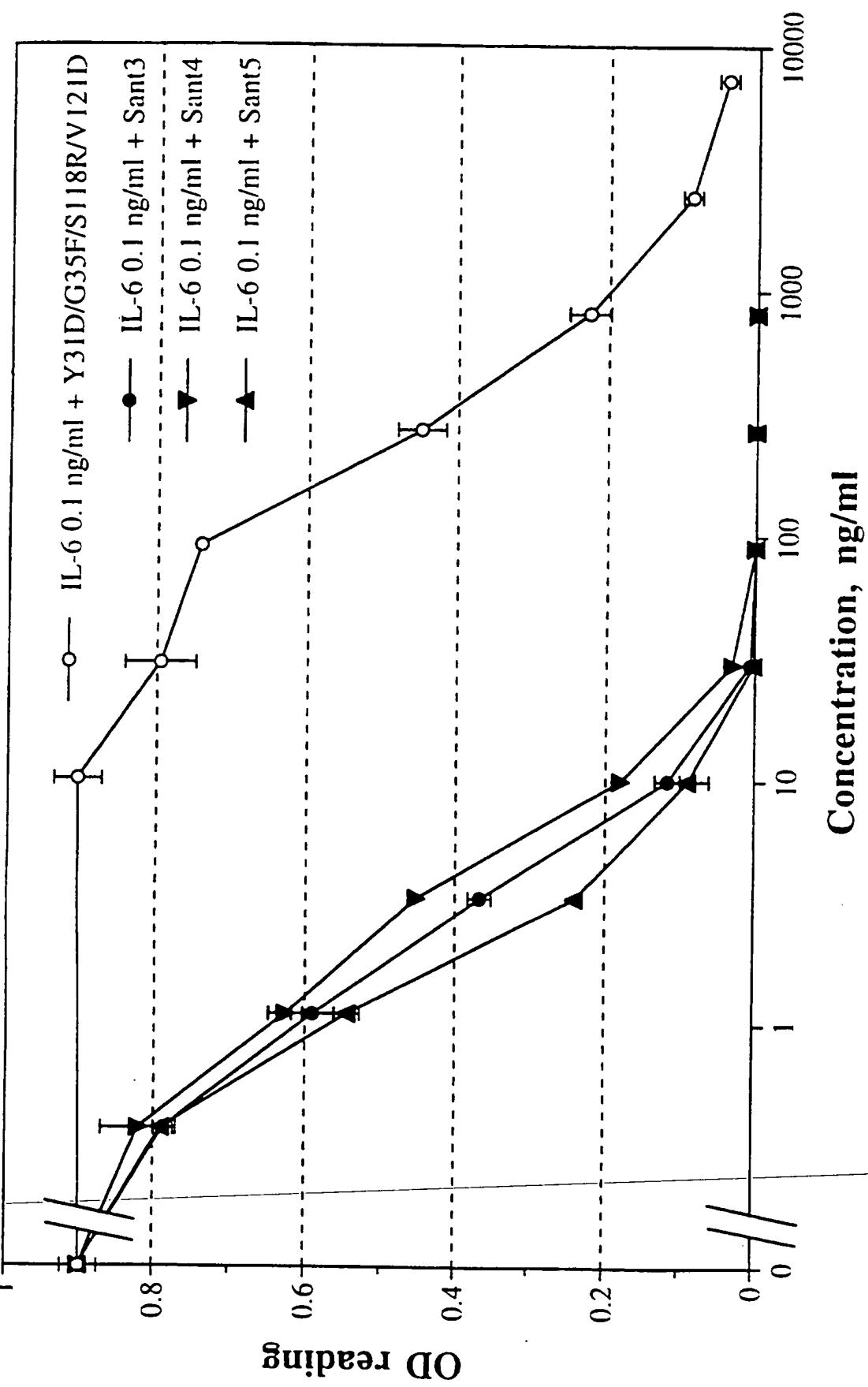


FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No

PCT/IT 95/00216

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 C07K14/54 A61K38/20 C12N15/24 G01N33/74

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C07K A61K C12N G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EMBO JOURNAL, vol. 13, no. 6, 15 March 1994 pages 1357-1367, XP 000565719 SAVINO, R. ET AL. 'Generation of interleukin-6 receptor antagonists by molecular-modeling guided mutagenesis of residues important for gp 130 activation' * whole disclosure * --- PROC. NATL. ACAD. SCI. USA, vol. 90, 1993 XP 000565720 SAVINO, R. ET AL. 'Saturation mutagenesis of the human interleukin 6 receptor binding site: Implications for its three-dimensional structure' * abstract; figs. 1-3 *	1-6
X	--- -/-	1-3,5,6

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search

26 March 1996

Date of mailing of the international search report

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Authorized officer

Hermann, R

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IT 95/00216

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO,A,94 09138 (CETUS ONCOLOGY CORPORATION) 28 April 1994 * claims 1-4 * ---	9,10,12
X	WO,A,94 11402 (ISTITUTO DI RICERCHE DI BIOLOGIA MOLECOLARE P. ANGELETTI S.P.A.) 26 May 1994 * page 1; claims * ---	1
A	J. IMMUNOL. , vol. 153, no. 4, 15 August 1994 pages 1744-1753, XP 000565715 EHLERS, M. ET AL. 'Identification of two novel regions of human IL-6 responsible for receptor binding and signal transduction' * abstract; p. 1746, left-hand column, last paragraph; p. 1749-1751 * -----	1-12
2		

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/IT 95/00216

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		CA-A-	2147466	28-04-94
		EP-A-	0672144	20-09-95
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WO-A-9411402	26-05-94	CA-A-	2129824	26-05-94
		EP-A-	0667872	23-08-95
		JP-T-	7501947	02-03-95
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